

WHAT IS CLAIMED IS:

1 1. A device for suturing an end of a first body duct to a hole in the
2 side of a second body duct, said device comprising:
3 a structure for holding the end of the first body duct and positioning said
4 end adjacent to the hole in the side of the second body duct; and
5 a plurality of needles arranged on the structure to be advanced along a
6 plurality of paths wherein each path first passes radially into and forwardly out of the end
7 of the first body duct and into the hole of the second body duct and then everts so that the
8 needles will pass outwardly through tissue peripheral to the hole when the end of the first
9 body duct is on the structure adjacent to the hole in the second body duct.

1 2. A device as in claim 1, wherein the structure comprises a shaft.

1 3. A device as in claim 2, wherein the shaft has a surface adapted to
2 receive the first body duct.

1 4. A device as in claim 3, wherein said surface comprises a
2 cylindrical surface adapted to received the first body duct.

1 5. A device as in claim 2, wherein the shaft has a tubular surface
2 against which the needles are positioned to guide said needles along a portion of said
3 path.

1 6. A device as in claim 2, wherein the shaft further comprises a
2 plunger for advancing said needles through the first body duct.

1 7. A device as in claim 6, wherein the plunger includes suture storage
2 for a plurality of sutures each coupled to one of said plurality of needles.

1 8. A device as in claim 6, wherein the plunger comprises a plurality
2 of elongate members for advancing said needles through the first body duct.

1 9. A device as in claim 8, wherein the elongate members comprise
2 tubes each containing a suture coupled to one of said needles.

1 10. A device as in claim 1, wherein the structure comprises a plurality
2 of guide channels which define said plurality of paths.

1 11. A device as in claim 10, wherein the guide channels are arranged in
2 a radial configuration about a shaft of said structure.

1 12. A device as in claim 10, wherein the guide channels comprise
2 guide tubes.

1 13. A device as in claim 10, wherein the guide channels have a
2 longitudinal slot along a length of at least of one said guide channels.

1 14. A device as in claim 10, wherein the guide channels each have a
2 first portion and a second portion, wherein the first and second portions are separated by a
3 gap which receives the end of the first body duct.

1 15. A device as in claim 10, wherein at least one of said guide channels
2 has a substantially curved configuration so that one of said needles passing through said
3 guide channel will evert to pass outwardly through tissue peripheral to the hole when the
4 end of the first body duct is on the structure adjacent to the hole in the second body duct.

1 16. A device as in claim 14, wherein the second portion of the guide
2 channel comprises a guide tube having a J-shaped section for guiding one of said needles
3 along a portion of said path.

1 17. A device as in claim 16, wherein the second portion of the guide
2 channel tube has a longitudinal slot extending along the length of the guide tube having a
3 J-shaped section.

1 18. A device as in claim 14, wherein the first body duct has a lumen, a
2 body duct wall, and an outer surface, and wherein:
3 the first portion of the guide channel is adapted to be positioned outside
4 the first body duct and has a distal opening positioned to open towards an outer surface of
5 the first body duct when the first body duct is mounted on the structure; and
6 the second portion of the guide channel is adapted to be positioned in the
7 lumen of the first body duct when the first body duct is mounted on the structure, said
8 second portion of the guide channel receiving one of said needles advanced from the first
9 portion and passing through the body duct wall.

1 19. A device as in claim 18, wherein the second portion of the guide
2 channel has a J-shaped configuration.

1 20. A device as in claim 18, wherein the second portion of the guide
2 channel includes a longitudinal slot extending the length of the second portion.

1 21. A device as in claim 18, wherein the needles are of sufficient
2 length to extend from the first portion of the guide channel, through the second portion,
3 and through the tissue layer of the second body duct.

1 22. A device as in claim 1, wherein said needles comprise a shape-
2 memory alloy.

1 23. A device as in claim 1, wherein said needles comprise a
2 superelastic material.

1 24. A device as in claim 1, wherein:
2 said needles each have an arcuate profile when unconstrained;
3 said structure comprises a tubular constraint having a lumen surface,
4 wherein the needles are movable between a first position within the tubular constraint
5 where said needles have a substantially straight configuration and a second position
6 within the constraint wherein said needles extend beyond the tubular constraint and
7 assume said arcuate profile.

1 25. A device as in 24, wherein said tubular constraint comprises an
2 inner tube coaxially mounted with an outer tube, said needles mounted on the distal end
3 of the inner tube wherein said inner tube is movable between a first and second position
4 with the outer tube.

1 26. A device as in claim 1, wherein the structure comprises:
2 an outer tube having a passage; and
3 an inner tube slidably mounted in the passage of the outer tube and having
4 the needles fixedly secured to a distal end thereof, said needles adapted to penetrate one
5 end of the first body duct when the body duct is mounted within said inner tube.

1 27. A device as in claim 26, wherein:
2 said needles each have an arcuate profile when unconstrained;

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3 said inner tube is movable between a first position within the outer tube
4 where said needles have a substantially straight configuration and a second position
5 within the outer tube wherein said needles extend beyond the outer tube and assume said
6 arcuate profile.

1 28. A device as in claim 26, wherein the inner tube has an opening in a
2 wall of the inner tube spaced apart from a distal end of the inner tube, said opening
3 allowing for the insertion of the first body duct into a lumen of the inner tube.

1 29. A device as in claim 26, wherein the inner tube is coupled to a
2 plunger which reciprocates said inner tube between a forwardly advanced position and a
3 retracted position.

1 30. A device as in claim 26, wherein the outer tube and inner tube are
2 in coaxial alignment and have a slideable relationship relative to each other.

1 31. A device as in claim 26, wherein each of said needles has a suture
2 attached to the distal end of said needles.

1 32. A device as in claim 26, wherein the needles have arcuate shape
2 memory so that they evert as they are advanced forward.

1 33. A device as in claim 32, wherein the needles have a sharpened tip
2 pointing proximally when the needles are in a substantially curved configuration.

1 34. A device as in claim 32, wherein said needles comprise a shape
2 memory material.

1 35. A device as in claim 26, wherein the needles in said second
2 position has a length sufficient to extend from the inner tube through a wall of the second
3 body duct such that a sharpened tip of the needle penetrates completely through said wall.

1 36. A device as in claim 26, wherein the needles have a releasable
2 connection with said inner tube.

1 37. A device as in claim 1, further comprising means for guiding said
2 needles through the first and second body ducts.

1 38. A device as in claim 37, wherein the means for guiding the needles
2 comprises a plurality of guide channels.

1 39. A device as in claim 37, wherein the means for guiding the needles
2 comprises a plurality of needles having an arcuate profile when unconstrained and
3 mounted within a tubular constraint, said needles movable between a first position where
4 the tubular constraint forces the needles to a substantially straight configuration and a
5 second position wherein the needle assumes a configuration exhibiting said arcuate
6 profile.

1 40. A method for suturing an end of a first body duct to a hole in the
2 side of a second body duct, said method comprising:

3 positioning the end of the first body duct adjacent to the hole in the second
4 body duct;

5 advancing a plurality of needles carrying a plurality of sutures along a
6 plurality of paths, wherein each path first passes radially into and forwardly out of the end
7 of the first body duct and into the hole of the second body duct and then everts so that the
8 needles will pass outwardly through tissue peripheral to the hole when the end of the first
9 body duct is on the structure adjacent to the hole in the second body duct; and

10 securing a portion of at least one of said sutures outside of the first body
11 duct to a portion of the suture outside of the peripheral tissue surrounding the hole in the
12 second body duct.

1 41. A method as in claim 40, wherein said positioning step includes
2 mounting said first body duct against a shaft structure containing said plurality of needles.

1 42. A method as in claim 40, wherein advancing the needles comprises
2 passing the needles through guide channel which define the paths.

1 43. A method as in claim 42, wherein the guide channels each have a
2 first portion and a second portion, where the first and second portions are separated by a
3 gap which receives the end of the first body duct.

1 44. A method as in claim 43, wherein advancing said needle comprises
2 passing said needle through said first portion of the guide channels, through the wall of
3 said first body duct, and into said second portion of the guide channels.

1 45. A method as in claim 40, wherein advancing the needles comprises
2 unconstraining said needles so that the each needles assume an arcuate, everted
3 configuration as they are passed forwardly.

1 46. A method as in claim 40, wherein advancing the needles comprises
2 using a plunger having a tubular structure releasably coupled to said needle to push said
3 needle along said path.

1 47. A method as in claim 40, wherein securing the sutures comprises
2 removing said sutures from said guide channels by lifting the sutures out of the channels
3 through a longitudinal slot running along a length of each of said guide channels.

1 48. A method as in claim 40, further comprising:
2 providing a suturing device having an inner tube coaxially mounted within
3 an outer tube, where at least one of said needles is made of a shape-memory alloy and is
4 mounted on the inner tube; and
5 extending said needles beyond the outer tube by relative motion between
6 the needle and the outer tube, said needle extended to a configuration where a sharpened
7 tip of the needle points substantially in a proximal direction.

1 49. A method as in claim 40, further comprising lifting said shaft
2 structure in a proximal direction to pull the needles through the peripheral tissue
3 surrounding the hole in the second body duct.

1 50. A method as in claim 40, further comprising evert the first body
2 duct over said needles.

1 51. A method as in claim 40, further comprising using a breakaway
2 catheter to facilitate introduction of the shaft structure into the second body duct.

1 52. A method as in claim 40, wherein securing said sutures comprises:
2 collecting sutures carried near a sharpened tip of said needles; and

3 tying off the sutures to connect the body ducts together.

1 53. A method as in claim 40, wherein the second body duct comprises
2 an artery.

1 54. A method as in claim 40, wherein the second body duct comprises
2 the aorta.

1 55. A method as in claim 40, wherein said advancing and securing
2 steps are performed on a beating heart.

1 56. A method as in claim 40, wherein said advancing and securing
2 steps are performed on a stopped heart.

1 57. A method as in claim 40, wherein said positioning, advancing, and
2 securing steps are performed minimally invasively.

1 58. A method as in claim 40, wherein said positioning, advancing, and
2 securing steps are performed in an open surgery environment.

1 59. A method as in claim 40, wherein said positioning, advancing, and
2 securing steps are performed through minimally invasive percutaneous openings in a
3 chest of a patient.

1 60. A method for suturing an end of a first body duct to a hole in the
2 side of a second body duct, said method comprising:

3 using a needle driver to simultaneously pass a plurality of sutures through
4 the end of the first body duct, inwardly through the hole of the second body duct, and
5 outwardly through peripheral tissue surrounding the hole in the second body duct; and
6 securing a portion of the suture outside of the first body duct to a portion
7 of the suture outside of the peripheral tissue surrounding the hole in the second body duct.

1 61. A method as in claim 60, wherein a plunger is used to pass a
2 plurality of needles through the end of the first body duct, wherein each of said needles
3 carries one of said sutures.

1 62. A kit comprising:
2 a graft suturing device adapted to deliver a plurality of needles;

3 instructions for use in suturing an end of a first body duct to a hole in the
4 side of a second body duct comprising using the graft anastomosis device to
5 simultaneously advance a plurality of needles radially into and forwardly out of the end of
6 the first body duct and into the hole of the second body duct and then evert so that the
7 needles will pass outwardly through tissue peripheral to the hole when the end of the first
8 body duct is on the device adjacent to the hole in the second body duct; and
9 a package adapted to contain the device and the instructions for use.